Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Computer Science 8 (2012) 165 – 170

Procedia
Computer Science

New Challenges in Systems Engineering and Architecting
Conference on Systems Engineering Research (CSER)
2012 – St. Louis, MO
Cihan H. Dagli, Editor in Chief
Organized by Missouri University of Science and Technology

Using System Architecture Maturity Artifacts to Improve Technology Maturity Assessment

Matin Sarfaraz[a], Dr. Brian J. Sauser[a], Edward W. Bauer[b]

[a]*Stevens Institute of Technology, Castle Point on Hudson, Hoboken, NJ 07030 USA*

[b]*US Army RDECOM-ARDEC, Picatinny Arsenal, Picatinny, NJ 07806 USA*

Abstract

The Technology Readiness Level (TRL) is a measurement used to assess the maturity of a technology prior to its inclusion in a system. It is a management tool utilized by program managers, project managers, and others in acquisition management to assess technology maturity. The TRL of a technology is determined by the assessment of Subject Matter Experts (SMEs) who examine the degree to which a criteria is being fulfilled. One of the current deficiencies in using TRLs is the subjectivity in determining the readiness value. This paper aims to reduce subjectivity in TRL maturity assessments by utilizing the maturity artifacts present in system architecture models. This paper will propose a technique and research methodology that can support TRL in technology maturity assessment in the design and development phase of a technology lifecycle.

Keywords: Decision Making; Technology Readiness Levels; System Architecture; DoDAF; Maturity Assessment

1. Introduction

In the area of technology management, program managers suffer from schedule slippages, cancellations, and failure to meet performance objectives. The GAO claimed that maturing new technology before it is included in a product is perhaps the most determinant factor in the success of the eventual product [1]. To that end, Technology Readiness Level (TRL) has proven to be a beneficial metric in assessing the risk associated with a developing or acquired technology. However, one of the deficiencies in using the TRL metric is that estimates of maturity are predominantly formulated by SMEs [2, 3]. Although there are guidelines and tools to support the assessment process such as the TRL calculator or

1877-0509 © 2012 Published by Elsevier B.V.
doi:10.1016/j.procs.2012.01.034

Report Documentation Page			Form Approved OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **29 FEB 2012**	2. REPORT TYPE	3. DATES COVERED **16-02-2012 to 29-02-2012**
4. TITLE AND SUBTITLE **Using System Architecture Maturity Artifacts To Improve Technology Maturity Assessment**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army RDECOM-ARDEC,Picatinny Arsenal,Picatinny ,NJ,07806**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

Procedia Computer Science, Volume 8, 2012, Pages , Pages 165?170,Government or Federal Purpose Rights License

14. ABSTRACT

The Technology Readiness Level (TRL) is a measurement used to assess the maturity of a technology prior to its inclusion in a system. It is a management tool utilized by program managers, project managers,and others in acquisition management to assess technology maturity. The TRL of a technology is determined by the assessment of Subject Matter Experts (SMEs) who examine the degree to which a criteria is being fulfilled. One of the current deficiencies in using TRLs is the subjectivity in determining the readiness value. This paper aims to reduce subjectivity in TRL maturity assessments by utilizing the maturity artifacts present in system architecture models. This paper will propose a technique and research methodology that can support TRL in technology maturity assessment in the design and development phase of a technology lifecycle.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

DoD Deskbook[4, 5], the final estimation of maturity is left to the evaluator(s), who make (s) the decision subjective [6].

It is the goal of this paper to present a more informed decision making method that will assist managers in measuring and tracking the progress and risks involved in maturity assessment. To accomplish this, maturity artifacts, the pieces of information needed by decision makers to make informed decisions, are identified and mapped to system architectural elements. Given the inaccuracy, imprecision, or lack of knowledge coupled with the complexity of engineering systems, this research attempts to improve upon decision making in the area of maturity assessment by providing more information for better grounded decisions.

To achieve the goal stated above, this paper explores the combined use of the Department of Defence Architecture Framework (DoDAF) and TRL metric in technology maturity assessment. System architectures facilitate decision making by conveying the necessary information to the decision maker by presenting architecture information, and the TRL provides a metric to assess the maturity of a technology at any given time. Architecture data supports acquisition program management and systems development by representing system concepts, design, and implementation as they mature over time, which enable and support operational requirements [7]. In the latest version of DoDAF, Meta Model (DM2) have been introduced to define concepts and models and to support Defence Acquisition System (DAS) and Planning, Programming, Budgeting, and Execution (PPBE), which are only two of the six core processes within DoD[8].

This research correlates maturity artifacts, the pieces of information needed by decision makers to make informed decision, to system architectural elements that are present in DoDAF 2.0 models. To achieve this, this research first identifies a set of DoDAF 2.0 models that are suitable for maturity assessment. The challenge to identify the set of DoDAF 2.0 models suitable for assessment becomes easier with the use of the TRL calculator tool. This research pairs each TRL calculator question to the best suited model(s) in DoDAF 2.0.A survey study will be used to demonstrate the effectiveness of this new approach in comparison to the current practice of using TRLs.

2. Literature Review

The use of technology maturity metrics within aerospace has been around since the introduction of TRL in the 1980’s [9]. Developed by United States (US) National Aeronautic and Space Administration (NASA), TRL is a nine level scale that describes the maturity of a technology with respect to a particular use [10]. Following its introduction, US government agencies (e.g. Department of Defense (DoD), Army, Department of Energy) and their contractors (the Sandia National Laboratory) adopted this scale [1, 9]. Tan has pointed out to the diverse ways that agencies and organizations have employed the TRL metric [6]. To support the use of TRL, the DoD has published Technology Readiness Assessment (TRA) Deskbooks [11, 12]. In 2002, William Nolte at AFRL developed and released the first TRL Calculator (it is a Microsoft Excel application) for both hardware and software [4]. The TRL Calculator attempts to fill for the lack of guidance on how to use TRLs by providing the program manager with a tool that can measure the maturity of a given technology [4]. The TRL Calculator tool provides a repeatable set of questions for determining a TRL. The TRL calculator works by answering a series of checklist questions. The answer to each question is assumed to be in a documentable form (reports, CONOPS, analysis, chart, etc.), and assumed to be available and collected prior to the beginning of assessment. In this research, we assume that information relating to maturity assessment can be found in the system architecture.

While the TRL metric has been sufficient at evaluating technology readiness, various authors have pointed to TRLs deficiencies [13]. Sauser et. al. pointed that TRLs overlook integration between two technologies, which led to in the development of the Integration Readiness Level (IRL) metric [14]. In addition, the TRL metric is a soft measure. Silvestro states, Soft measures are those which are qualitative, judgmental, subjective, and based on perceptual data [15]. The lack of formal method of implementing TRLs has also contributed to claims of subjective assessments, which can be due to biased technology developers and the broad interpretation for the definitions of each TRL level [13]. Despite these deficiencies, the TRL is the metric of choice for DoD to guide a technology through the lifecycle development phases.

In the mid 1990s, the DoD determined that a common approach was needed for describing its architectures, so that DoD systems could efficiently communicate and interoperate during joint and multinational operations [16]. In 2009, DoDAF 2.0 was introduced, taking the focus away from models and placing emphasis on data. Aside from DoDAF 2.0's new features that can help in acquisition processes and technology management, researchers have studied using DoDAF in Technology Management. Dimov [17] presented a architecture-oriented modelling approach to assist in acquisition systems for one of Bulgaria's force-management's subsystems. Hughes from the Air Force Institute of Technology used a concept maturity model to help to uncover the unknowns that plague a system development [18]. He suggested using maturity elements to assess and mature a concept at a given decision point. Philips introduced Human Readiness Level to complement TRL in program risk management structures, and synthesized the technical details of Human View in relation to DoDAF [19].

DoDAF 2.0 introduced new views (i.e. PV-2, SvcV-9, SV-9) and architecture modelling primitives to support collection or architecture content that can be used for maturity assessments. Another feature introduced in DoDAF 2.0 was Fit-for-Purpose (FFP) models. FFP models are useful in decision making, and enable the architect to focus on collecting and creating views that are necessary for the decision maker's requirements, and focusing the architecture to align to the decision-maker's needs [20]. The survey of literature body shows a gap in the application of DoDAF models in maturity assessment using the TRL metric. The identification of models and maturity artifacts is advantageous to the practice of systems engineering, helping in utilizing systems architectures to make more informed decisions.

3. Research Approach

This research will propose a new method for technology maturity assessment. Once this method is developed, a survey study will be used to collect data for statistical analysis. Subject Matter Experts for a particular program will be asked to rate the technology maturity using two different methods: the new method and current TRL procedure. The information gathered by the survey study will be used to determine if there is a statistically significant difference between using this new technique and the current practice of using TRLs. For this, the aggregated SME inputs would be used to determine mean and variation for each practice to test the hypothesis. If a statistically significant difference is observed from the collected data, then the hypothesis is accepted.

The technique this research uses to pair maturity elements to DoDAF views and artifacts is achieved in two steps. In the first step, maturity elements derived from the TRL calculator checklist were grouped to three categories. This aids in understanding the maturity element, but more importantly, this step is a necessity for step 2. This paper utilizes Conceptual Data Model (CDM), which is one of the new three levels of DoDAF Meta Models (DM2) introduced in DoDAF 2.0. The CDM defines concepts involving high-level data constructs from which Architectural Descriptions are created, enabling executives and managers at all levels to understand the data basis of Architectural Description [8]. In Figure 1, key concepts are grouped into three categories (Ways, Means, and Ends) to facilitate the collection and usage of architecture related data.

				Description of each key concept as it relates to Maturity Assessment
Ways	Behavior	Activity		Work that transforms inputs (Resources) into outputs (Resources) or changes their state.
		Measure		The magnitude of some attribute of an individual.
		Rule	Agreement	A consent among parties regarding the terms and conditions of activities
			Standard	A formal agreement documenting accepted specifications or criteria for products, processes, procedures
	Links	Relationship		A connection, association, or involvement.
		Interaction		The interaction between two components or systems, sending data.
Means	Resources	System		A functionally, physically, and/or behaviorally related group of interacting or interdependent elements.
		Service		A mechanism to enable access to capabilities, access provided using interface. Uses Resources
		Organization		A specific real-world assemblage of people and other resources organized for an on-going purpose.
		Person/Skill		The ability, coming from one's knowledge, practice, aptitude, etc., to do something well.
		Material/HW/SW		Equipment, apparatus or supplies that are of interest, without distinction as to application
		Info/Data	Data	Information suitable for communication, interpretation, or processing by humans or machines
			Information	The state of a something of interest that is materialized -- in any medium or form -- and communicated or received.
Ends	Results	Project/Task		Planned activities that aim to change the state of some situation. A temporary endeavor to create Resources or Desired Effects
		Capability		The ability to achieve a Desired Effect under specified (performance) standards and conditions, by using ways and means
		Goal/Effect		How goals, visions, objectives, and effects relate and bear on architectures. A desired state of a Resource

Figure 1: Most popular DM2 Conceptual Data Model concepts used for categorizing maturity artifacts

In the second step, the CDM is mapped to a DoDAF model. Through the use of CDM, we can bridge between the checklist questions in TRL calculator and views that support technology maturity assessment in DoDAF. Figure 2 shows the mapping of a CDM to DoDAF views. Since each CDM is used in more than one DoDAF related model, the selection of model could prove a challenge. Researchers familiar with DoDAF may have easier time mapping this step, but there are plenty of publications and reports that summarize the use for DoDAF related models, and can assist in accomplishing this activity[21].The identification of maturity artifacts and CDM can lead to the appropriate selection of DoDAF model(s) best suited for storing and managing maturity artifacts. Following the process above, Figure 3 shows a sample maturity to DoDAF model alignment for two levels of the TRL Calculator checklist.

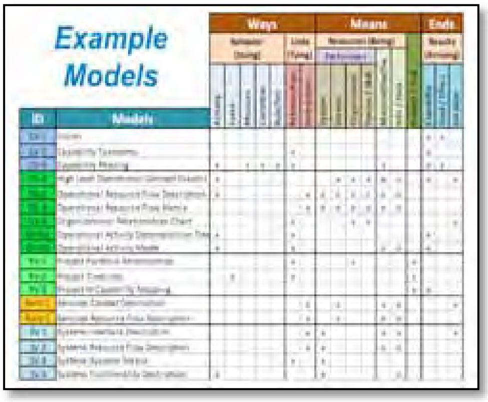

Figure 2: Mapping CDM to DoDAF Models[21]

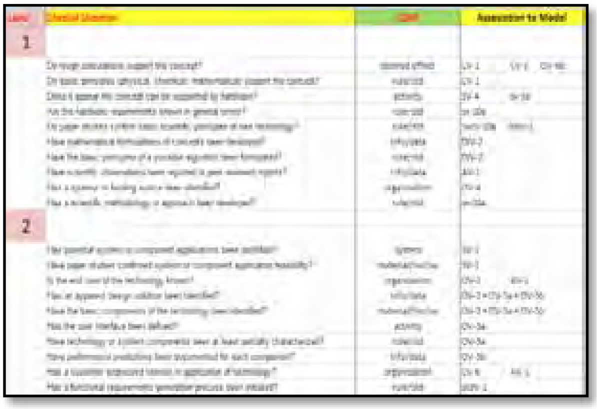

Figure 3: Mapping of TRL checklist to DoDAF-related Models

Delphi method is used to collect and benefit from the knowledge of the expertise and practitioners in this field. Delphi method originated in a series of studies that the RAND Corporation conducted in the 1950's. The objective was to develop a technique to obtain the most reliable consensus of a group of experts [22, 23]. Delphi may be characterized as a method for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem [22]. A Delphi Survey has three main tasks. First, defining and describing the topic and preparing questions to send experts; second, selection of a panel of participating experts; and third, organizing and running the survey[24]. The input received from the SME is going to be vital in a better identification of DoDAF model suitable for assessment, but the development of FFP models that can allow managers in using DoDAF in program development.

4. Conclusion and Future Works:

Far too often have decision makers have been forced to make decisions based on insufficient data, resulting in projects that are over-budget and over-schedule. This paper introduces a new technique that incorporates the use of DM2 CMEs to assist in the characterizations of maturity elements. Given the increase application of system architectures in organizations and government agencies, this paper aims to examine the application of DoDAF 2.0 in technology management. This is possible by capturing information through a structured documentation process. The increased availability of data and increased transparency among reviewers decreases the risk of uninformed decision making when available information is determined to be insufficient or missing, leaving less room for uninformed decision making.

The future works for this research includes survey study, and execution of Delphi method to collect the knowledge of SME in better identifying and selecting DoDAF models. In addition, Delphi method will allow on the development of FFP models, which is strongly encouraged for DoDAF 2.0[8]. The authors of this research strongly recommend mapping the integration readiness levels to DoDAF models as well, which shall be vital for more informed decision making in system maturity assessment.

5. References

[1] GAO, *Best practices : better management of technology development can improve weapon system outcomes : report to the Chairman and Ranking Minority Member, Subcommittee on Readiness and Management Support, Committee on Armed Services, U.S. Senate*. Washington, D.C., 1999.
[2] B. J. Sauser and J. E. Ramirez-Marquez, "System Development Planning via System Maturity Optimization," in *IEEE Transactions onEngineering Management* vol. 56, ed, 2009, pp. 533-548.
[3] N. Azizian, S. Sarkani, et al., "A Comprehensive Review and Analysis of Maturity Assessment Approaches for Improved Decision Support to Achieve Efficient Defense Acquisition," in *World Congress on Engineering and Computer Science*, San Francisco, CA, 2009.
[4] W. Nolte*, et al.*, "Technology readiness level calculator, Air Force Research Laboratory," presented at the NDIA Systems Engineering Conference, 2003.
[5] DoD, "Technology Readiness Assessment (TRA) Deskbook," ed. Washington DC: DUSD (S&T) U.S. Department of Defense, 2009.
[6] W. Tan*, et al.*, "A probabilistic approach to system maturity assessment," *Systems Engineering,* vol. 14, pp. 279-293, 2011.
[7] DoDAF. (2007). *DoD Architecture Framework version 1.5*. Available: http://cio-nii.defense.gov/docs/DoDAF_volume_I.pdf
[8] DoDAF. (2009). *DoDAF Introduction*. Available: http://cio-nii.defense.gov/sites/dodaf20/introduction.html
[9] B. Sauser*, et al.*, "Integration Maturity Metrics: Development of an Integration Readiness Level," *Information, Knowledge, Systems Management,* vol. (in press), 2010.
[10] C. Dion-Schwarz, "How the Department of Defense Uses Technology Readiness Levels," T. a. L. Office of the Under Secretary of Defense for Acquisition, Ed., ed, 2008.
[11] DoD, "Technology Readiness Assessment (TRA) Deskbook," ed. Washington DC: DUSD (S&T) U.S. Department of Defense, 2003.
[12] DoD, "Technology Readiness Assessment (TRA) Deskbook," ed. Washington DC: DUSD (S&T) U.S. Department of Defense, 2005.
[13] S. e. a. Conford, "Quantitative methods for maturing and infusing advanced spacecraft technology," in *IEEE Aerospace Conference Proceedings:*, 2004, pp. 663-681.
[14] B. Sauser*, et al.*, "A Systems Approach to Expanding the Technology Readiness Level within Defense Acquisition," *International Journal of Defense Acquisition Management,* vol. 1, pp. 39-58, 2008.
[15] S. Rhian*, et al.*, "Quality Measurement in Service Industries," *International Journal Of Service Industry Management,* vol. 1, 1990.
[16] C. K. a. C. Sibbald, "Modeling DoDAF Compliant Architectures with UML 2," Telelogic white paperMay 2004 2004.
[17] A. Dimov*, et al.*, "Using Architectural Models to Identify Opportunities for Improvement of Acquisition Management," *Information & security : an international journal.,* vol. 23, pp. 188-206, 2009.
[18] R. C. Hughes, "Development of a concept maturity assessment framework," 2010.
[19] E. L. Phillips and S. Naval Postgraduate, "The development and initial evaluation of the human readiness level framework," Naval Postgraduate School, Monterey, California, 2010.
[20] M. Wayson, "DoDAF v 2.0 Introduction," O. o. t. D. D. CIO, Ed., ed, 2009, pp. 10-16.
[21] J. N. Martin, "Part 2: Architecture Development," in *Architecture Frameworks & Modeling*, ed, 2011, pp. 40-45.
[22] C. Okoli and S. D. Pawlowski, "The Delphi method as a research tool: an example, design considerations and applications," *Information & Management,* vol. 42, pp. 15-29, 2004.
[23] N. Dalkey and O. Helmer, " An Experimental Application Of The Delphi Method To The Use Of Experts," *Management Science,* vol. 9, pp. 458-467, 1963.
[24] J. Steurer, "The Delphi method: an efficient procedure to generate knowledge," *Skeletal Radiology,* vol. 40, pp. 959-961, 2011.